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CONIFER DAMAGE AND MORTALITY ASSOCIATED WITH HIGHWAY DE-ICING AND SNOW REMOVAL IN THE LAKE TAHOE AREA

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John Kliejunas, Melissa Marosy, and John Pronos
Plant Pathologists

ABSTRACT

Vegetation adjacent to the major highways in and near the Lake Tahoe area was surveyed to determine the cause of foliar damage and mortality. Symptoms of injury observed were characteristic of salt damage, either by absorption through the root system or direct contact, and of mechanical abrasion. Foliar and soil analyses confirmed excessive levels of sodium and chloride as the cause. Primary pathogens or insects were not involved in the observed roadside damage and mortality. Management alternatives, including no change, decrease in salt usage, use of alternative chemicals, removal of susceptible vegetation from along right-of-ways, and favoring resistant species, are discussed.

USDA, FOREST SERVICE, PACIFIC SOUTHWEST REGION
State and Private Forestry, Forest Pest Management
630 Sansome Street, San Francisco, California 94111

INTRODUCTION

At the request of Forest Supervisor Geri Bergen, Tahoe National Forest, a field evaluation of conifer damage and mortality along the Highway 20, Highway 89 and Interstate 80 corridors was conducted by Forest Pest Management. Salt and mechanical damage from highway de-icing and snow removal were suspected as the cause.

The objectives of the evaluation were to verify salt damage and mechanical abrasion as the cause of the roadside conifer damage and mortality, to determine if other factors, including drought, insects or diseases, were associated with the damage, and to provide pest management alternatives for consideration by managers to maintain the integrity of the visual corridors.

METHODS

Roadside Survey

Vegetation along Interstate 80 from Alta to the Nevada border, Highway 20 from Nevada City to I-80, and Highway 89 north of Truckee to Sierraville were examined on May 9 and 10, 1989. Because of the extensive damage observed, the survey was expanded to include highways around Lake Tahoe, including Highways 89, 267, 28, and Highway 50 to Placerville (Figure 1). Portions of the highways within the Tahoe National Forest boundaries were re-examined on May 30 with Jane LaBoa, silviculturist, and Armando Garza, engineer, Tahoe National Forest; Jerry Westfall, silviculturist, Nevada City Ranger District; and Karen Jones, timber management officer/silviculturist, and Jerry Kent, salvage sale officer, Truckee Ranger District.

Symptoms of salt damage (Leiser et. al., 1980; Miller, 1978; Scharpf and Srago, 1974; Scharpf and Srago, 1978) were noted and a damage rating system (Scharpf and Srago, 1974) described in Appendix 2 was used where appropriate to quantify the severity of foliar symptoms. Damaged and healthy trees of all size classes throughout the area were examined for the presence of insect and disease pests.

Foliar and Soil Analyses

To confirm the accuracy of diagnostic symptoms used to identify salt-damaged trees, foliar and soil samples were collected at various locations (Figure 1) during the week of June 5, 1989. Foliage was collected at eleven locations from vegetation exhibiting typical symptoms. These samples were generally from trees or shrubs within 20 feet of the highway. Control samples from the same species, but from individuals with no foliar symptoms, were collected from nearby sites at each of the eleven locations. Data, including species, diameter, estimated height, damage rating, and distance from the highway, were recorded for each sampled tree. Samples were placed in paper bags and submitted to Chemistry Lab Services, California Department of Food and Agriculture, in Sacramento for sodium and chloride analyses. Total sodium and chloride content was determined by the water extraction technique, after comparison with the total acid digestion method, for each sample on a dry weight basis. A total of 50 samples from seven conifer species and two brush species was analyzed.

Soil samples were collected at each of the eleven locations and at three additional locations. Control samples were collected at nearby sites where foliar damage was not apparent. At each location, approximately 500 grams of soil from a depth of 2 to 6 inches were collected, placed in plastic bags and submitted to the Analysis and Identification Branch, Division of Plant Industry, California Department of Food and Agriculture, in Sacramento for analyses of total ion content. Soil salt levels were determined by preparing a 1:2 water extract (200 grams of soil mixed with 400 milliliters of distilled water), and measuring electroconductivity (milllimhos) of water decanted after agitation and settling of the mixture.

RESULTS

Roadside Survey

Damage and mortality were highly visible and essentially continuous above 4000 feet elevation along all the highways where conifers occurred, and appeared especially severe on lodgepole pine along I-80 and Highway 89, and on incense-cedar, white fir and Jeffrey pine along Highway 89 on the west side of Lake Tahoe in the Emerald Bay and Rubicon Bay areas. The damage was usually adjacent to or within 20 to 50 feet of the highway edge and generally extended further into the forest on the downslope side. In some locations, Donner Summit and Emerald Bay for example, needle tip dieback typical of salt absorption through the soil was observed 300 to 400 feet downslope from the road.

Damage was observed on all conifer species, including Douglas-fir; ponderosa, Jeffrey, sugar and lodgepole pines; white fir; and incense-cedar. Initially, the rating system of Scharpf and Srago (1974) was used to quantify symptoms. However, it became apparent that when damage did occur, most conifers were moderately to severely affected. Symptoms included tip burning or dieback of pine, Douglas-fir and true fir needles and incense-cedar leaves (Figures 2, 3 and 4). Symptoms usually appeared first on oldest needles in the lower crown, then progressed upwards and into last year's foliage. As entire needles became necrotic, needle loss occurred, giving the crowns a thin appearance. Needle loss was especially noticable on affected Douglas-fir. With incense-cedar, dead branchlets tended to remain on the trees rather than be cast.

In many cases, a browning or burning of the foliage, rather than a progressive tip dieback of needles, occurred only on the side of the trees facing the highway, and lower foliage (presumably covered by snow during the winter months) was not affected. These symptoms suggested damage from direct foliar absorption of salt and mechanical abrasion following plowing and blowing of snow, ice, salt, sand and cinders, rather than from salt absorption through the soil.

Leaf tip burning of various brush species, including pinemat manzanita (Arctostaphylos nevadensis), greenleaf manzanita (A. patula) and squaw carpet (Ceanothus prostratus), was observed at numerous locations. These brush species also exhibited evidence of direct absorption of salt and burning of foliage on the side adjacent to highways. Decidious hardwood species had not yet leafed out, and therefore, foliar symptoms were not evident.

Primary insect or disease organisms were not directly associated with tip burning or mechanical abrasion symptoms. Pests, including mountain pine beetle (Dendroctonus ponderosae) in lodgepole pine, dwarf mistletoe (Arceuthobium camylopodum) on Jeffrey pine, and elytroderma needle disease (Elytroderma deformans) on Jeffrey pine were noted only ocassionally on roadside trees. There was no evidence of bark beetle attack or evidence of Armillaria or other root disease pathogens.

Mortality of conifers, in particular white fir, associated with drought and subsequent fir engraver (Scolytus ventralis) attack, was evident in surrounding forests. However, this mortality was observed only in mature mixed conifer forests some distance from the highways, and was not associated with roadside trees with symptoms of salt damage and mechanical abrasion.

Many of the large overstory trees examined in May with mostly necrotic foliage had healthy appearing cambium and inner bark at the root collar, indicating that they were not dead. These trees had no evidence of bark beetle attack. A few understory white fir with symptoms of needle tip burn had been recently attacked by secondary wood borers. Flushes of new, current-year growth on many conifer species, especially the pines, in early June indicated some recovery and tended to mask the severity of damage.

Foliar and Soil Analyses

Levels of both sodium and chloride were consistently higher in foliage collected from vegetation with moderate to severe damage ratings than in foliage collected from vegetation with no damage (Table 1). Some of the highest levels of sodium and chloride (.58% sodium and 1.37% chloride) were found in damaged white fir and Jeffrey pine foliage at Donner Summit, collected within a drainage 250 feet downslope from Interstate 80. The mean chloride content at all locations was 0.14 percent in tissue from healthy foliage compared to 1.04 percent in foliage with symptoms. Mean sodium levels were also higher in damaged foliage (0.41%) than in healthy foliage (0.12%). Levels of sodium and chloride were especially high in Douglas-fir and incense-cedar foliage with salt damage symptoms (Table 2). The range of chloride levels found generally followed the severity of damage symptoms observed, with Douglas-fir and incense-cedar being highest; white fir and lodgepole pine intermediate; and Jeffrey, ponderosa and sugar pines and brush species being lowest.

Electroconductivity readings were at low levels in all soils sampled (Table 3), probably because salts are rapidly leached from soils. For example, soils from location number 6, which had electroconductivity readings of 0.00 millimhos, were collected during a rain and hailstorm. Even though readings were low, they were, with the one exception, consistently higher in soils collected from beneath trees with salt damage symptoms than in soils collected from beneath trees without visible damage. The mean electroconductivity reading of soils collected beneath conifers with moderate to severe damage was more than three times higher than the mean reading from soils collected from beneath conifers without visible damage (0.13 vs. 0.04 millimhos).

DISCUSSION

Foliar damage and conifer mortality observed adjacent to all the highways surveyed are characteristic of salt damage, either by absorption through the root system or direct contact, and of mechanical abrasion. These damage symptoms have been well-documented and are unique to salt (Leiser et. al., 1980; Marshall, 1984; Miller, 1978; Scharpf and Srago, 1974; Scharpf and Srago, 1978; Sucoff, 1975). Soil and foliar analyses confirmed excessive levels of sodium and chloride as the primary cause.

Both sodium and chloride contribute to symptoms, but past studies (Leiser et. al., 1980; Scharpf and Srago, 1974) indicate that leaf chloride concentration is a better indicator of the salt status of the plant, relative to damage rating, than is the leaf sodium concentration. Levels of salt we measured in the soil were low, with readings of above 0.60 millimhos being considered harmful to salt-sensitive plants. However, even though salts are leached readily from soil and readings would vary with time of year samples are taken, we found consistently higher levels in soils from beneath trees with salt damage symptoms than in soils from beneath trees without symptoms.

In this study, the mean concentrations of sodium and chloride in the foliage of moderately to severely damaged trees were several times greater than the mean concentrations found in the foliage of trees without damage symptoms. The levels of sodium and chloride found in Jeffrey pine, white fir and incense-cedar foliage are slightly higher, but comparable to, those found in Scharpf and Srago's (1974) study. For example, they reported mean percent dry weight of chloride in Jeffrey pine foliage with a moderate damage rating as .535, and with a severe damage rating as .855. We found 0.89 percent in Jeffrey pine foliage with a moderate to severe damage rating.

We found no evidence that primary pathogens or insects were involved in the observed damage and mortality of roadside conifers and brush species. This agrees with the 1980 University of California at Davis study (Leiser et. al., 1980). However, secondary organisms may eventually come in on trees stressed by the salt damage. Injury to trees is additive. Needle loss over at least the last 2 years due to excessive salt is a tremendous stress factor, probably much more so than any stress due to pathogens, insects, or drought.

The drought of the last few years has probably played only a relatively minor role in the extremely high levels of salt damage and subsequent mortality observed adjacent to highways this last winter. Reduced levels of precipitation would certainly stress trees and concentrate salt levels in soils because of less leaching. However, precipitation levels in the Lake Tahoe area this last winter were at or near normal. Drought stress alone would not explain the dramatic increase in symptoms, damage, and mortality observed over the last few years.

The best correlation between the observed increase in conifer damage and mortality is with the increase in the use of salt. Salt usage on roads where damage and mortality is occurring has increased greatly (Table 4). Tons of salt used on District 3 roads has more than doubled over the last 10 years, and has consistently increased over the last four seasons from 8.8 tons in 1984-1985 to 19.5 tons this last winter.

MANAGMENT ALTERNATIVES

1. No change. The current bare pavement practice (keeping major highways open and clear of snow and ice whenever possible) would continue and salt application rates would remain at current levels or increase. Similar amounts of conifer damage and mortality would be expected. Salvage of merchantable trees and removal of nonmerchantable trees would continue. Removal of trees killed immediately adjacent to highways will not reduce salt runoff downslope into forest soils, and will possibly increase runoff into water. In fact, removal of the screening effect of roadside trees will likely extend damage further into the forest as blown snow, ice and salt extend further. Visible damage will be reduced because of the lack of vegetation, but visual quality, especially on roads adjacent to Lake Tahoe where large overstory trees have been killed, will be impaired.

If salt damage cannot be minimized because of human safety factors, then continuing mortality of vegetation, lack of roadside trees, and reduced visual quality need to be accepted as the trade-off. To accomplish this, an educational program, explaining to publics why salt damage is occurring and thought to be necessary, could be initiated.

2. Decrease salt usage. If less salt were used, there would be less damage to trees and other vegetation. Using less salt would reduce symptoms and mortality, and would reduce damage downslope. Evidence for this is abundant. However, using less salt may result in more chain controls during severe weather conditions. The resulting slowing of traffic and possible increase in hazardous driving conditions may not be acceptable to all publics.

Salt usage over the last decade has increased dramatically with no apparent correlation between amounts used and weather conditions. Techniques increasingly employed elsewhere to apply adequate, but not excessive, amounts of salt include salt-sand mixtures, calibrated dispensers on trucks, closer supervision of actual applications, and use of alternative chemicals.

3. Use alternative chemicals. Several alternative chemicals to sodium chloride are available, and effective. A liquid, reduced corrosion road deicer, marketed under the trademark Freezgard + PCL, is apparently as effective as sodium chloride in clearing pavement. Cost of the material is several times greater than the cost of sodium chloride. The product was tested on a small scale by the California Department of Transporation this last winter. However, the environmental effects of the product are largely unknown. Because the product is high in chloride content, containing 25 percent magnesium chloride, its impact on vegetation and water quality should be evaluated before large scale use is implemented. A similar product containing 28 to 35 percent magnesium chloride has been used on dirt roads for dust abatement and soil stabilization. This product has caused burning of conifer foliage and killing of vegetation when roots come in contact with the chemical.

A second compound, CMA (calcium magnesium acetate), is also very effective, but did not deice as fast as sodium chloride in tests on Highway 395 in Mono and Inyo counties in California. The current cost of the product (about $650 per ton compared to about $40 per ton for sodium chloride) makes widespread use unlikely at the present time.

4. Remove susceptible vegetation from along right-of-ways. Removal of all vegetation from right-of-ways would reduce mortality and hazard from dead trees, and would, in some areas, increase sunlight to reduce ice formation. However, this would result in reduced visual quality, especially around Lake Tahoe. Furthermore, removal may extend damage from blown snow and salt further into public and private stands adjacent to right-of-ways, and will not prevent runoff of salt downslope to susceptible vegetation or into water.

5. Favor resistant species. Dead trees removed could be replaced with salt tolerant species to maintain vegetative cover along roadsides. When both rate of salt uptake and leaf damage are considered, literature (Leiser et. al., 1980) suggests that incense-cedar is most sensitive, white fir is intermediate, and pines are most tolerant to salt. However, our observations and results of foliar analyses indicated very little difference in damage or tolerance to salt among conifers at existing rates of salt usage.

Planting of resistant species may be acceptable along Interstate 80 and Highway 50 if rates of salt application are reduced, but would adversely affect visual quality along highway 89 adjacent to Lake Tahoe where damage to mature mixed conifer forests exists. Planting resistant species would not reduce runoff of salt and would, therefore, do nothing to reduce salt damage to conifers occurring in drainages several hundred feet or more from the highways.

LITERATURE CITED

1. Leiser, A.T., Palaniyandi, R., Paul, J.L., and R. Raabe. 1980. Highway operation and plant damage. Final Report, FHWA/CA/TL-80/03. Dept. Environmental Horticulture, Univ. Calif. Davis. 249 p.

2. Marshall, J.P. 1984. Evaluation of vegetation damage along Nevada highways in the Lake Tahoe Basin. USDA Forest Service, Intermountain Region, Forest Pest Management Report No. 84-3. Boise. 15 p.

3. Miller, P.R. 1978. Abiotic diseases. Pages 5-41 in R.V. Bega, Tech. Coordinator, Diseases of Pacific Coast Conifers. USDA Forest Service, Agriculture Handbook No. 521. 206 p.

4. Scharpf, R.F., and M. Srago. 1974. Conifer damage and death associated with the use of highway deicing salt in the Lake Tahoe Basin of California and Nevada. Technical Rept. 1, Forest Pest Control, USDA Forest Service, California Region. 16 p.

5. Scharpf, R.F., and M. Srago. 1978. How to diagnose road-salt injury in California conifers. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley. 8 p.

6. Sucoff, E. 1975. Effect of deicing salts on woody vegetation along Minnesota roads. Univ. Minn. College of Forestry, Minnesota Agricultural Experiment Station, Technical Bulletin 303. 49 p.

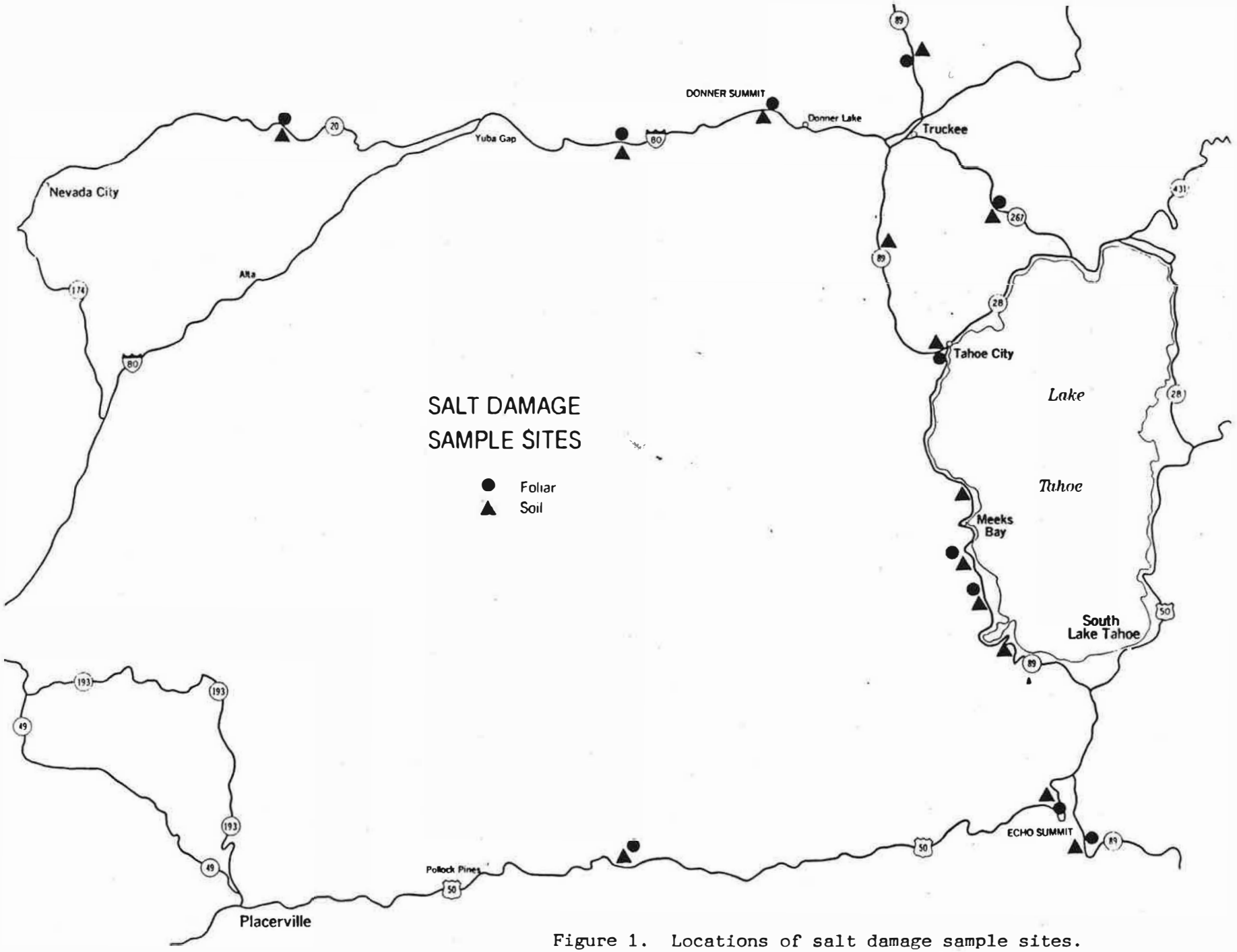

Figure 1. Locations of salt damage sample sites.

Figure 2. Salt damage symptoms on roadside white fir, Jeffrey pine and incense-cedar. Only trees immediately adjacent to the highway are injured.

Figure 3. Progress dieback of incense-cedar foliage as a result of salt accumulation.

Figure 4. Tip dieback of lodgepole pine needles. Note the sharp margin between the brown, dead tips and the remaining green of the needles characteristic of salt damage, and the new growth developing from the uninjuried bud.

Table 1. Percent dry weight of sodium and chloride found in the foliage of conifers and brush species sampled at eleven locations along highways in and near the Lake Tahoe area, by location.

Location[1]	Damage Rating[2]			
	None (Control)		Moderate/Severe	
	Sodium	Chloride	Sodium	Chloride
1	0.19	0.35	0.37	1.00
2	0.12	0.24	0.32	0.99
3	0.10	0.08	0.58	1.37
4	0.10	0.06	0.40	0.69
5	0.09	0.12	0.46	0.60
7	0.10	0.13	0.23	0.99
9	0.10	0.12	0.46	1.16
10	0.13	0.12	0.32	0.71
12	0.12	0.15	0.25	1.65
13	0.11	0.06	0.44	0.96
14	0.14	0.11	0.73	1.28
Mean	0.12	0.14	0.41	1.04

[1] See Figure 1 and Appendix 1 for descriptions of locations.

[2] See Appendix 2 for definitions of damage ratings.

Table 2. Percent dry weight of sodium and chloride found in the foliage of conifers and brush species sampled at eleven locations along highways in and near the Lake Tahoe area, by species.

Species	Number Sampled[1]	Damage Rating[2]			
		None (Control)		Moderate/Severe	
		Sodium	Chloride	Sodium	Chloride
Pinemat manzanita (PM)	1	0.14	0.14	0.29	0.35
Ponderosa pine (PP)	2	0.21	0.25	0.60	0.62
Greenleaf manzanita (GM)	1	0.11	0.13	0.22	0.72
Sugar pine (SP)	2	0.12	0.08	0.26	0.84
Jeffrey pine (JP)	5	0.11	0.08	0.44	0.89
Lodgepole pine (LP)	3	0.11	0.09	0.39	1.04
White fir (WF)	6	0.10	0.25	0.39	1.15
Incense-cedar (IC)	3	0.15	0.30	0.38	1.32
Douglas-fir (DF)	2	0.17	0.15	0.55	1.59

[1]Number sampled for each of the two damage rating classes.

[2]See Appendix 2 for definitions of damage ratings.

Table 3. Electroconductivity (millimhos) of soil samples collected at 14 locations along highways in and near the Lake Tahoe area.

Location[1]	Damage Rating[2]	
	None (Control)	Moderate/Severe
1	0.15	0.24
2	no data	0.23
3	0.01	0.18
4	0.01	0.21
5	0.00	0.00
6	0.04	0.08
7	0.00	0.06
8	0.03	0.08
9	0.02	0.03
10	0.02	0.07
11	0.06	0.12
12	0.04	0.07
13	0.02	0.44
14	0.06	0.07
Mean	0.04	0.13

[1] See Appendix 1 for descriptions of locations.

[2] See Appendix 2 for definitions of damage ratings.

Table 4. Salt used by the District 3 California Department of Transportation on 363 miles of roads in Sacramento, El Dorado, Placer, Nevada and Sierra counties (John Allison, CALTRANS District 3).

Season	Tons of salt
1975 - 1976	6,005
1976 - 1977	4,037
1977 - 1978	6,890
1978 - 1979	8,778
1979 - 1980	9,884
1980 - 1981	4,021
1981 - 1982	9,425
1982 - 1983	13,996
1983 - 1984	10,271
1984 - 1985	8,835
1985 - 1986	10,814
1986 - 1987	14,099
1987 - 1988	17,992
1988 - 1989	19,500

APPENDIX 1 -- Locations of Foliar and Soil Samples (continued)

Location Number	Location Description	Soil Sample Number	Foliar Sample Number	Damage Rating[1]	Species[2]	Feet From Road	DBH (in)	Height (ft)	Other Pests	Comments
4	89N,	8		severe		5				at foliar 23
	Prosser	9		healthy		150				at foliar 24
	Campground		21	severe	JP	5	2	8	none	
			22	healthy	JP	100	2	10	none	
			23	severe	LP	5	2	8	none	
			24	healthy	LP	150	2	8	none	
5	Highway 267,	16B		severe		adjacent				
	North Star	17		healthy		25				
			25	severe	WF	5	2	10	none	
			26	healthy	WF	75	3	15	none	
6	89S, about	18		moderate		adjacent				mature JP, WF
	8 miles S of	19		healthy				across (west) road and upslope		
	Truckee									
7	89S, 2 miles	20		severe						
	S of LTBMU	21		healthy						
	boundary at		27	moderate	WF	5	3	20	none	
	Craigs Sites		28	healthy	WF	30	3	20	none	
			29	moderate	GM	5	NR[3]	NR	none	
			30	healthy	GM	10	NR	NR	none	
8	89S, county	22		severe		adjacent				
	line, Sugar	23		healthy		200 ft				
	Pine Pt. SP									
9	89S;	24		severe		10				downslope
	Rubicon Bay	24		healthy		100				upslope
			31	severe	WF	5	6	30	none	
			32	healthy	WF	100	8	35	none	
			33	moderate	JP	10	5	30	none	
			34	healthy	JP	120	6	30	none	

APPENDIX 1 -- Locations of Foliar and Soil Samples (continued)

Location Number	Location Description	Soil Sample Number	Foliar Sample Number	Damage Rating[1]	Species[2]	Feet From Road	DBH (in)	Height (ft)	Other Pests	Comments
10	89S; just	26		severe		adjacent				
	S of north	27A		healthy		30				in stand
	entrance, D.L.		35	moderate	SP	5	5	30	none	
	Bliss SP		36	healthy	SP	150	34	90	none	
			37	moderate	JP	5	6	35	none	
			38	healthy	JP	150	6	35	none	
			39	moderate	PM	5	NR	NR	none	
			40	healthy	PM	10	NR	NR	none	
11	89S; just	27B		severe		20		downslope (100' JP dying)		
	N of Emerald	28		healthy		50				upslope
	Bay SP entrance									
12	89S; 3 miles	29		severe		adjacent				
	S of 89/50	30		healthy		150				upslope
	intersection		43	severe	IC	3	3	20	none	
			44	healthy	IC	150	3	18	none	
13	Highway 50,	31		severe		adjacent				
	Echo Summit	32		healthy		100				upslope
			45	severe	LP	5	2	8	none	
			46	healthy	LP	150	6	25	none	
14	Highway 50,	33		moderate		adjacent				
	1/4 mile W	34		healthy		100				upslope
	of Ice House		47	severe	DF	5	3	15	none	
	Road		48	healthy	DF	30	5	25	none	
			49	severe	PP	5	3	20	none	
			50	healthy	PP	25	4	25	none	

[1] See Appendix 2 for definitions of damage ratings.

[2] Refer to Table 2 for species abbreviations.

[3] NR = Not Recorded

APPENDIX 2

Damage Rating System (Scharpf and Srago, 1974):

No Damage -- No tipburn or needle browning.

Light Damage -- Damage to one-third or less of the foliage, with only the very tips of the needles showing tipburn.

Moderate Damage -- One-third to two-thirds of the foliage damaged, and one half or less of the length of the damaged needles on pines showing tipburn.

Severe Damage -- Two-thirds or more of the foliage damaged, and on pines 50 percent or more of the needle length showing tipburn. Trees completely brown and apparently dead were included in this category.